Offshore Wind Technology

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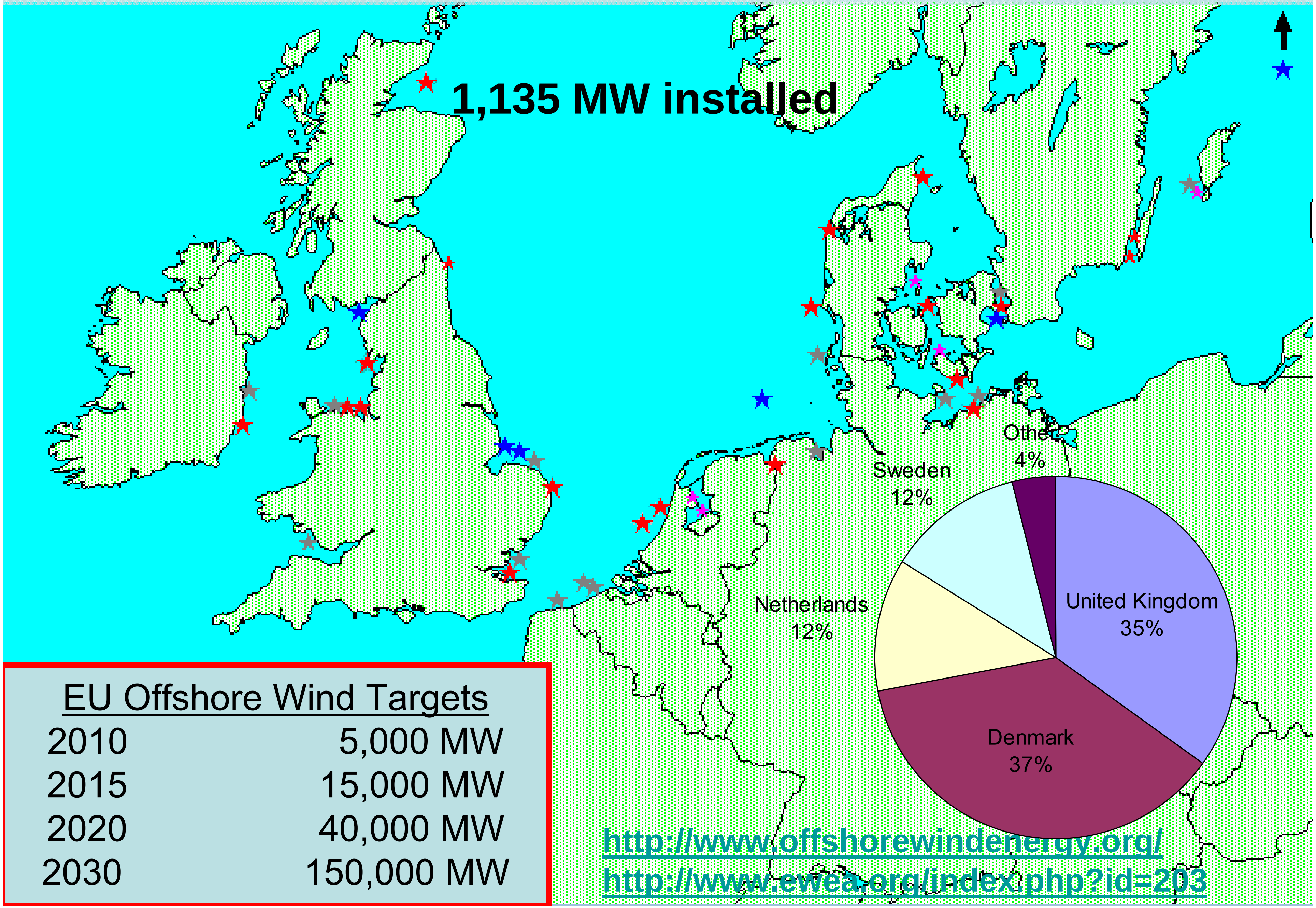
Great Lakes Wind on the Water Meeting

June 11, 2008

European Activity Offshore



EU Offshore Wind Targets

2010	5,000 MW
2015	15,000 MW
2020	40,000 MW
2030	150,000 MW

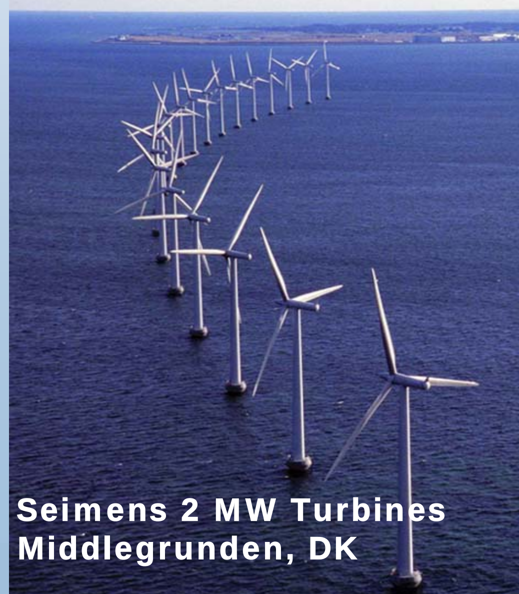
http://www.offshorewindenergy.org/
http://www.ewea.org/index.php?id=203

Offshore Technology Status


Vestas 2.0 MW Turbine
Horns Rev, DK


Talisman Energy:
Repower 5-MW
Beatrice Fields,
Scotland


GE 3.6 MW Turbine
Arklow Banks


Seimens 2 MW Turbines
Middlegrunden, DK

- Initial development and demonstration stage; 22 projects, 1135 MW installed
- Fixed bottom shallow water 0-30m depth
- 2 – 5 MW upwind configurations
- 70+ meter tower height on monopoles and gravity base
- Mature submarine power cable technology
- Existing oil and gas experience essential
- Reliability problems and turbine shortages have discouraged early boom in development.
- Cost are not well established in the US.

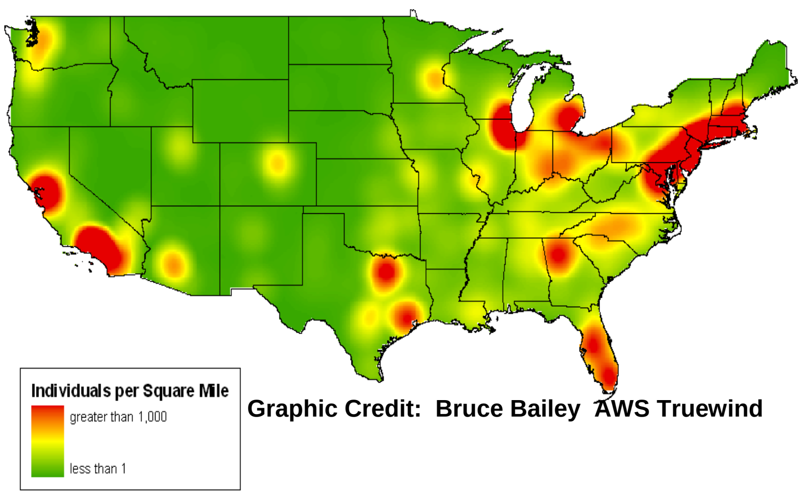
Why Offshore?

28 coastal states use 78% of the electricity in US

Many Coastal Load Centers Cannot Be Served by Land-based Wind

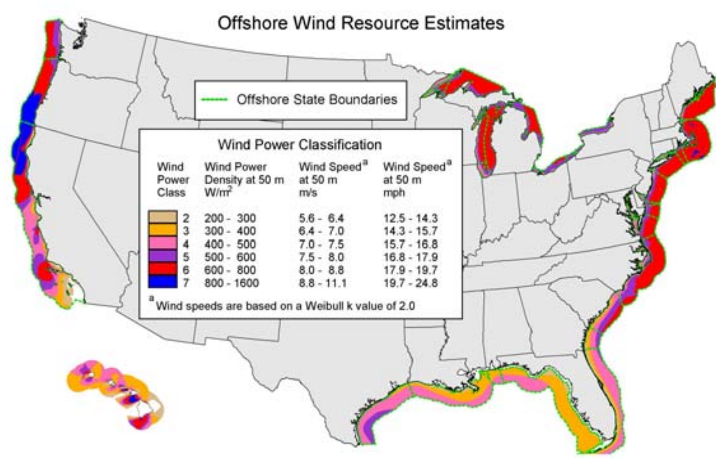
20% Wind Energy Goals Cannot be Achieved Without Offshore Contributions

US Population Concentration



Graphic Credit: Bruce Bailey AWS Truewind

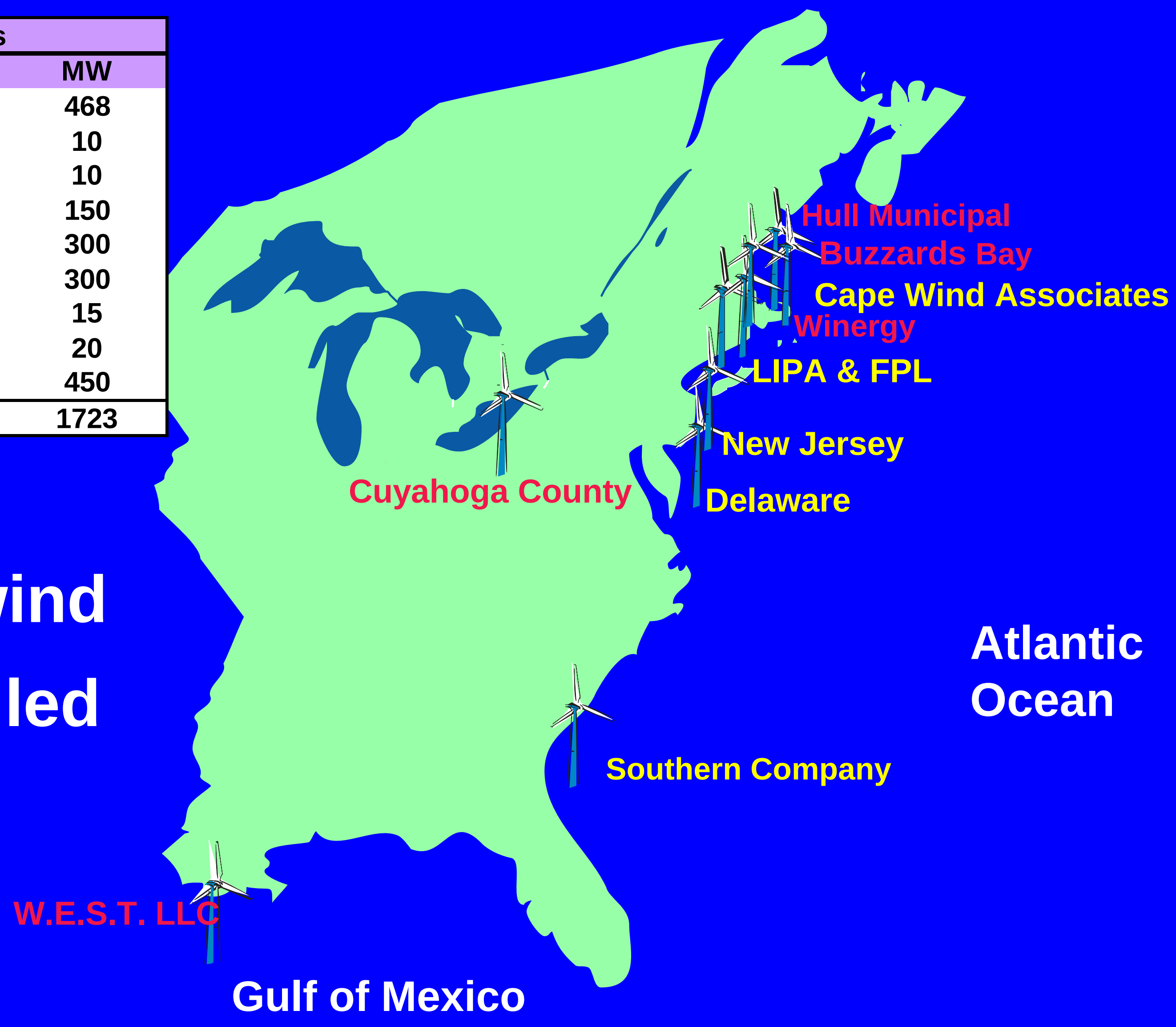
U.S. Wind Resource



US Projects Proposed

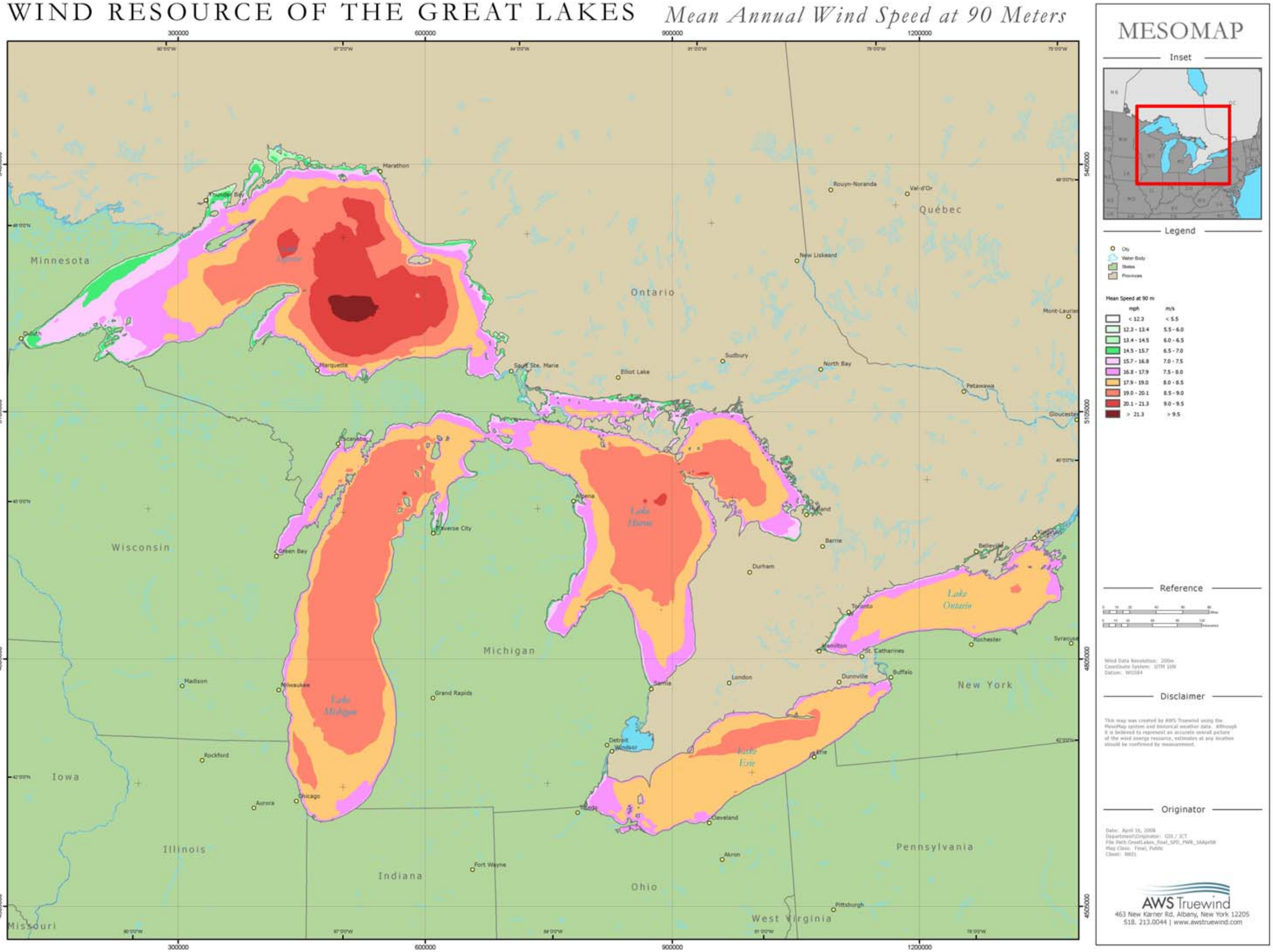
US Offshore Projects		
Project	State	MW
Capewind	MA	468
Winergy (plum Island)	NY	10
Southern Company	GA	10
W.E.S.T.	TX	150
Buzzards Bay	MA	300
New Jersey	NJ	300
Hull Municipal	MA	15
Cuyahoga County	OH	20
Delmarva	DE	450
Total		1723

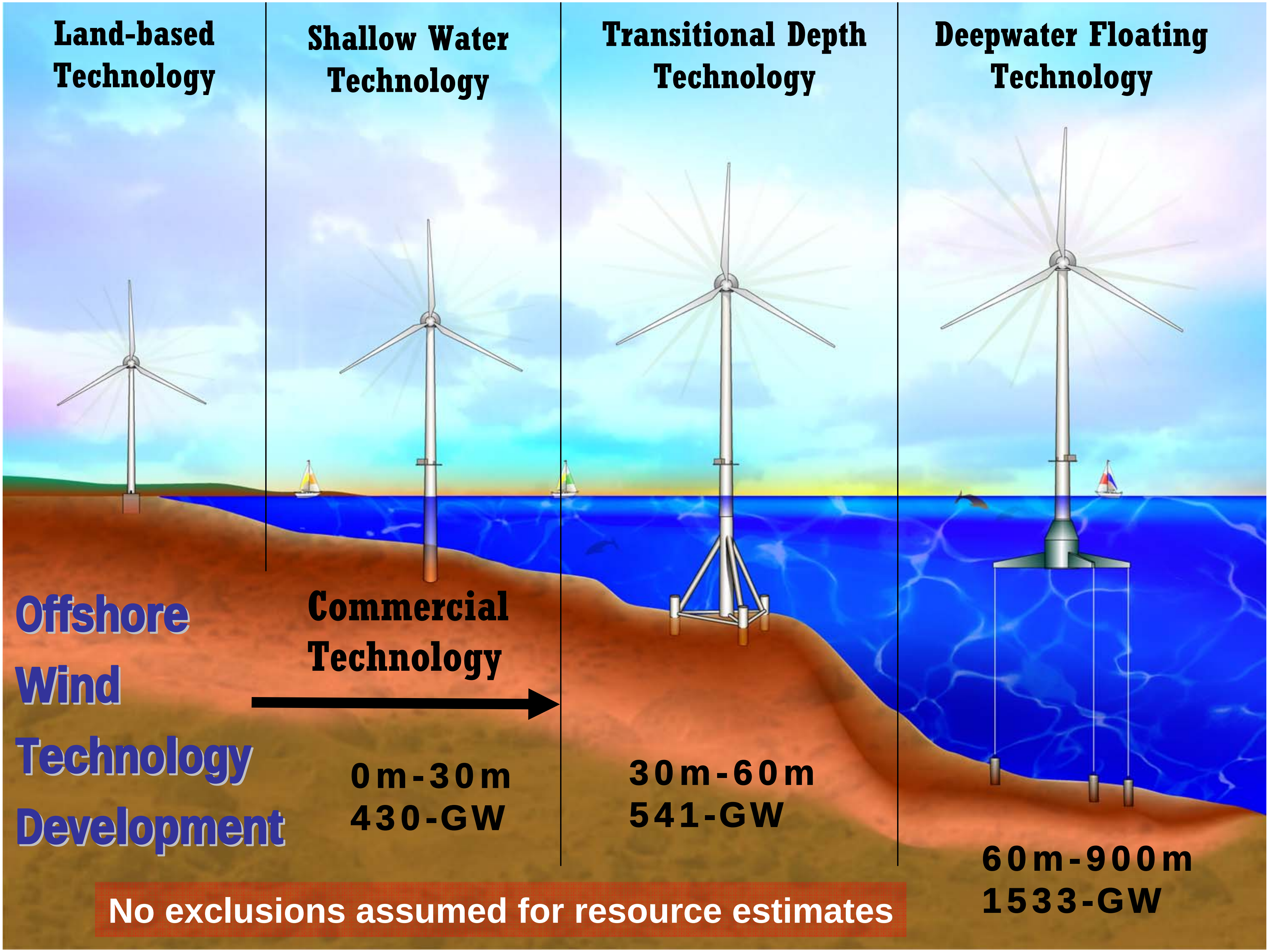
No Offshore wind projects Installed in U.S. yet



WIND RESOURCE OF THE GREAT LAKES

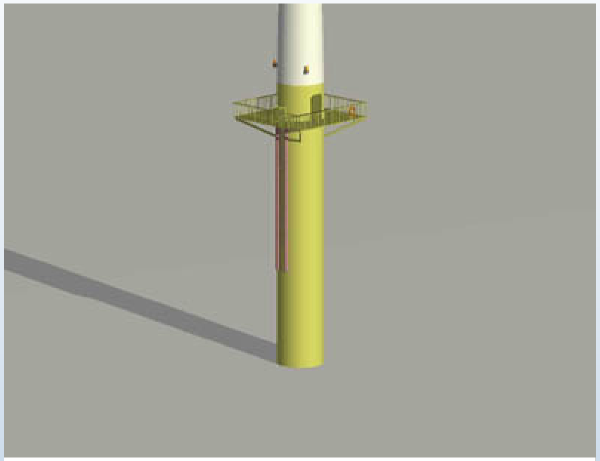
Mean Annual Wind Speed at 90 Meters




Land-based Technology
Shallow Water Technology
Transitional Depth Technology
Deepwater Floating Technology
Offshore Wind Technology Development
Commercial Technology
0m-30m
430-GW
30m-60m
541-GW
60m-900m
1533-GW
No exclusions assumed for resource estimates

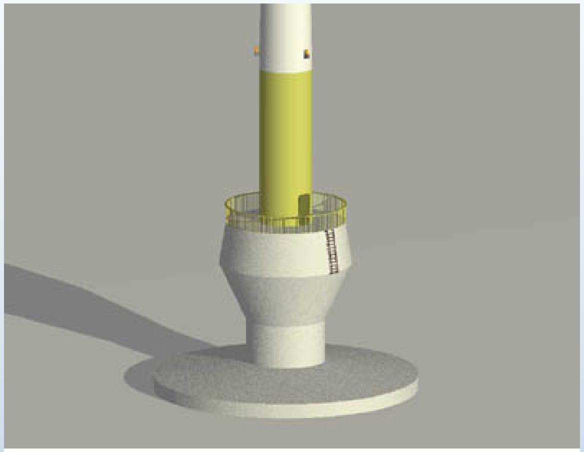
Foundation Types

Proven Shallow Water Designs | Transitional



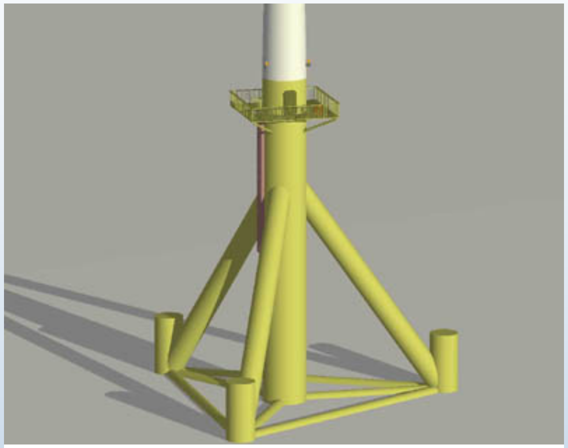
Monopile Foundation

- ➢**Most Common Type**
- ➢**Minimal Footprint**
- ➢**Depth Limit 25-m**
- ➢**Low stiffness**



Gravity Foundation

- ➢**Larger Footprint**
- ➢**Depth Limit 20m**
- ➢**Stiffer but heavy**

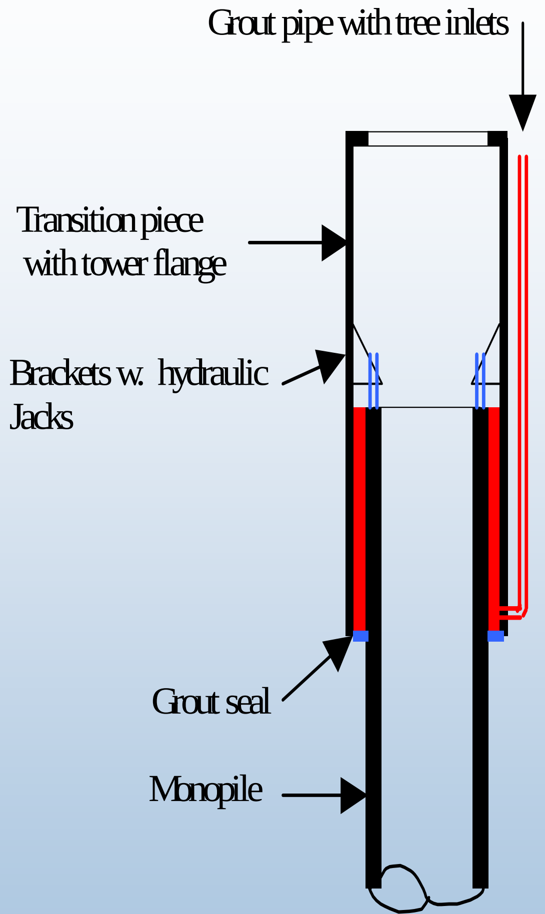


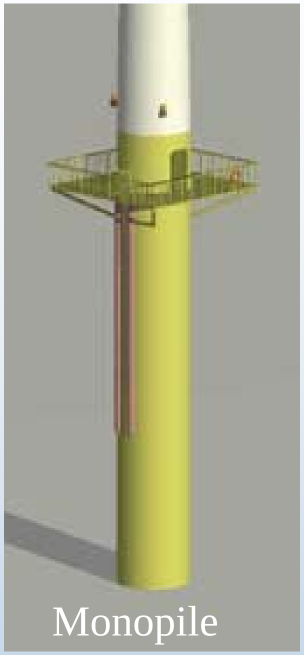
Tripod/Truss Foundation

- ➢**No wind experience**
- ➢**Oil and gas to 450-m**
- ➢**Larger footprint**

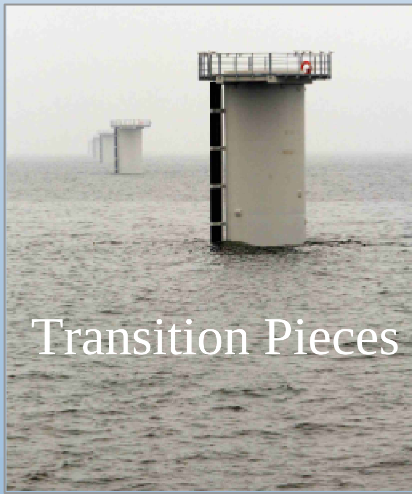
Graphics source: http://www.offshorewindenergy.org/

Monopile Foundations – Shallow Water



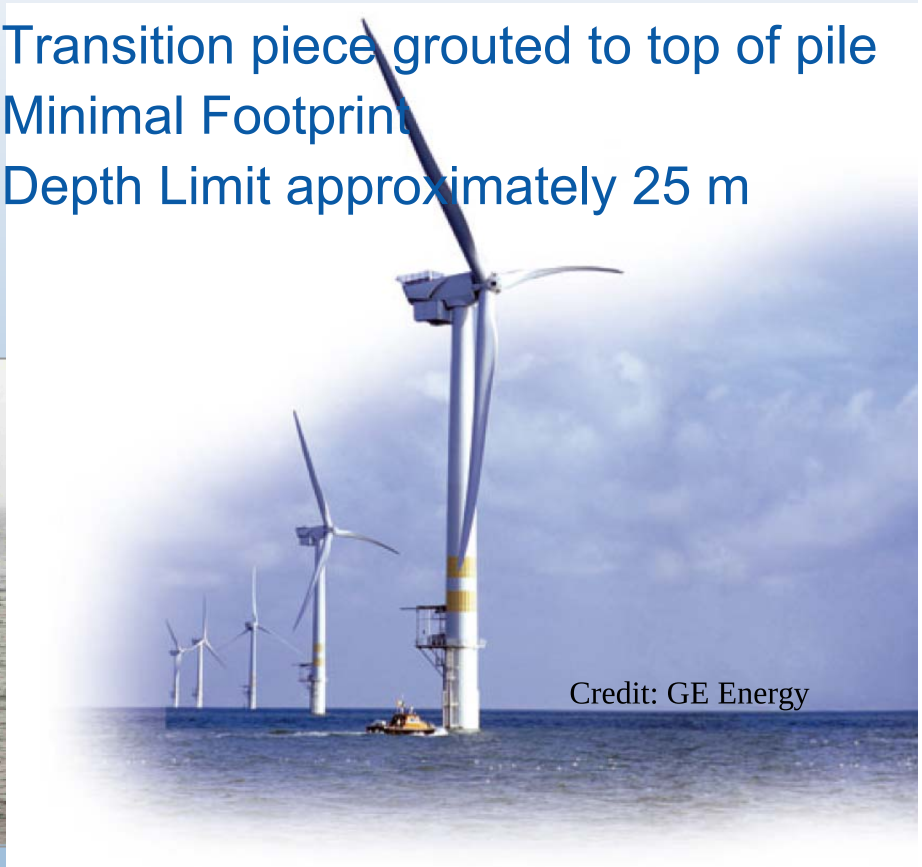


Monopile



Transition Pieces

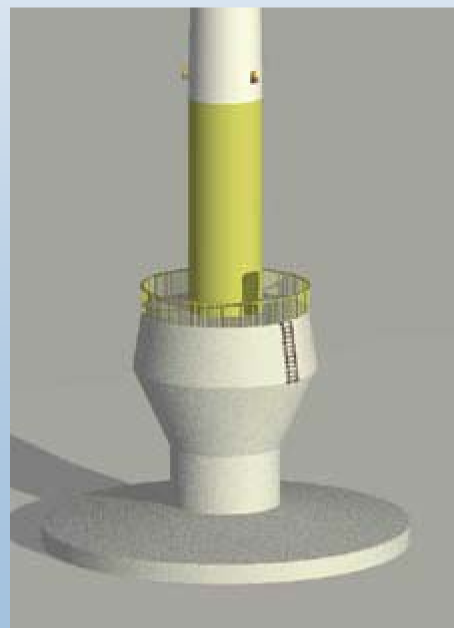
- Most Common
- Steel Tube
- Typically 4.5 - 5 m dia
- Thickness 30 - 60 mm
- Driven/drilled 25-30m embedment
- Transition piece grouted to top of pile
- Minimal Footprint
- Depth Limit approximately 25 m



Credit: GE Energy

Gravity Base Foundations

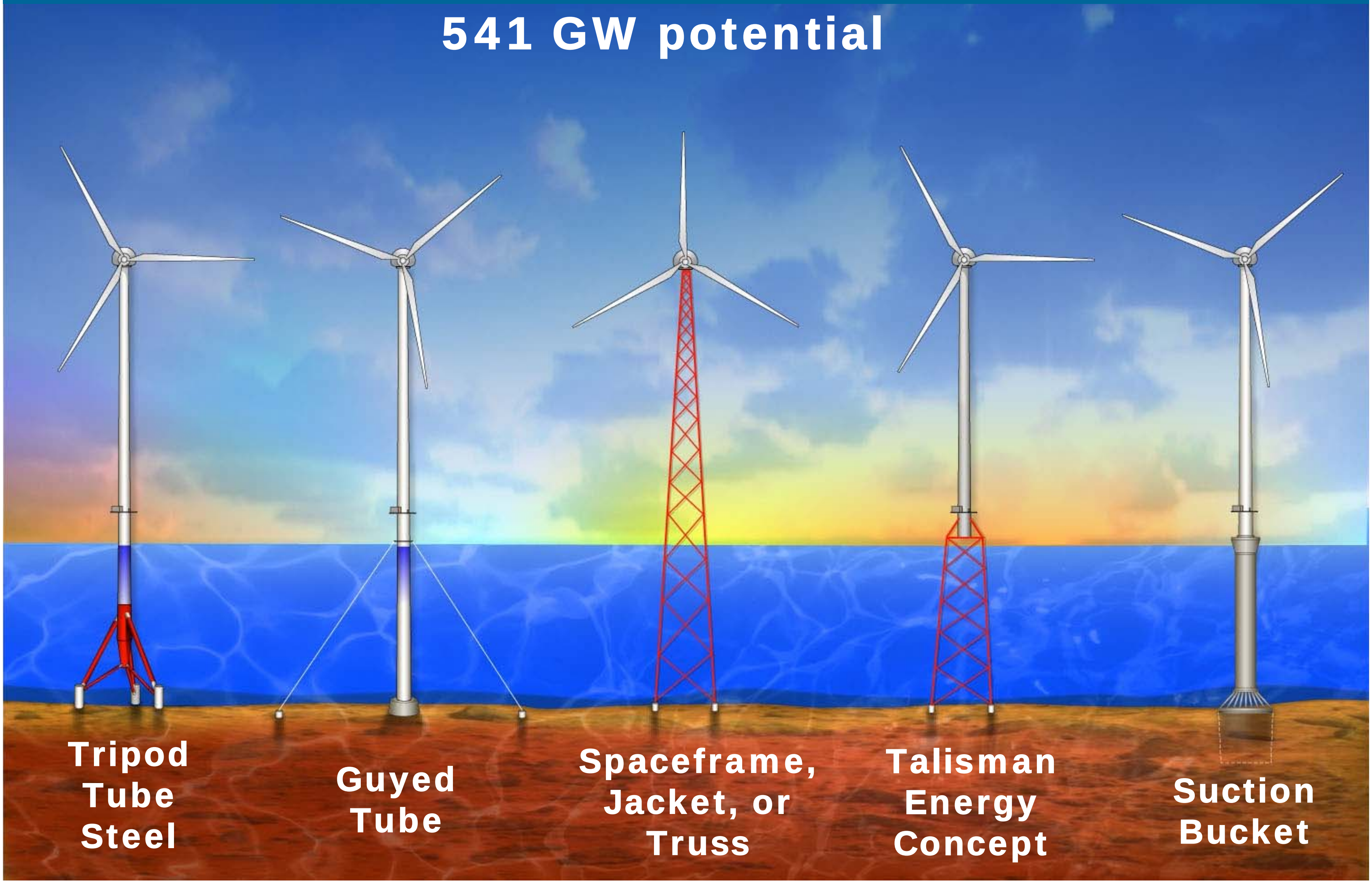
Shallow Water < 30-m



- Steel or concrete
- Relies on weight of structure to resist overturning
- Ballast may be required
- Seabed preparation essential
- Can be susceptible to scour
- Float-out installation
- Suitable for shallower sites
- Used by Siemens Turbines at Nysted and Samso

Transitional Depth Foundations

30-m to 60-m Depths



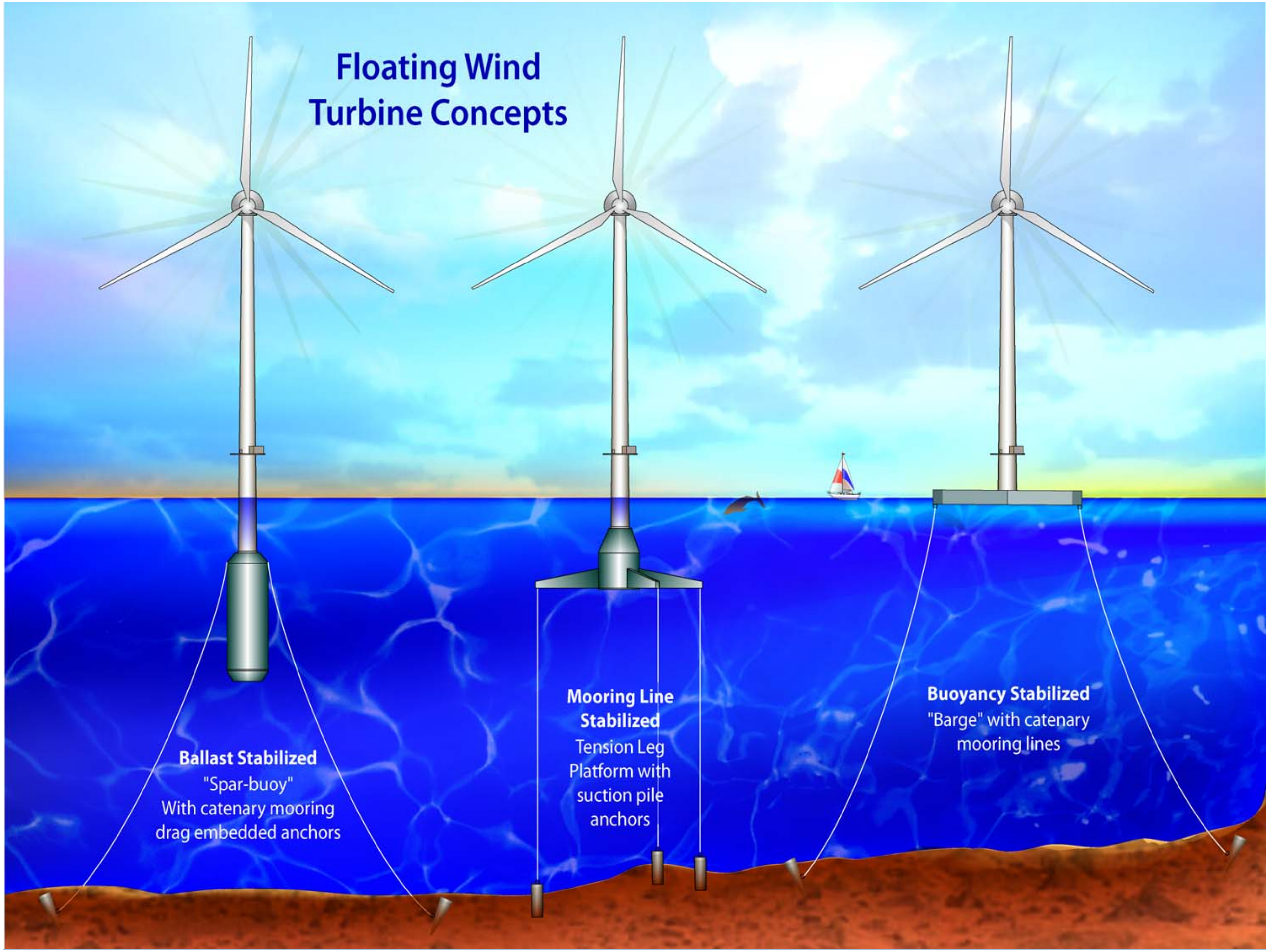
Substrucuture Loadout

Photo Credit: **Talisman Energy**

45-m Depth Offshore Demonstration Project
Talisman Energy in Beatrice Fields

- 5-MW Rating
- 61.5-m Blade Length
- Worlds Largest Turbine
- Two Machines
- 45-m Water Depths

Photo Courtesy: Talisman Energy


Floating Wind
Turbine Concepts
Ballast Stabilized
"Spar-buoy"
With catenary mooring
drag embedded anchors
Mooring Line
Stabilized
Tension Leg
Platform with
suction pile
anchors
Buoyancy Stabilized
"Barge" with catenary
mooring lines

HyWind Floating Wind Turbine Project
Spar – Ballast Stabilized

- Under development by StatoilHydro – Norway
- Most advanced floating wind energy system concept.
- Needs 100-m+ depth to operate.
- Announced a $78MM demonstration project near Norway.
- Partnering with Siemens using their 2.3MW turbine.
- Costs estimated about where solar is today.
- Expectations to compete with conventional wind energy long term.

BlueH Floating Wind Turbine Project

Tension Leg Platform – Mooring Line Stabilized

- First company to claim in-the-water floating wind turbine status.
- Deployed tension leg concept near Italy in late 2007.
- Demonstration was incomplete.
  - No energy generation.
  - No mooring lines fixed to bottom.
  - Turbine was undersized for platform.
  - No data collected.

Offshore Wind Energy Cost

↓ **Downward Cost Drivers**

- **Deployment**
  - ↓ **Learning Curve**
  - ↓ **Mass production**
  - ↓ **Infrastructure development**
  - ↓ **Experience lowers uncertainty**
- **Technology Improvements**
  - ↓ **High reliability components**
  - ↓ **Multi-megawatt turbines**
  - ↓ **Optimized offshore systems**

↑ **Upward Cost Pressures**

↑ **Turbine Supply Shortages**

↑ **Commodity price increases**

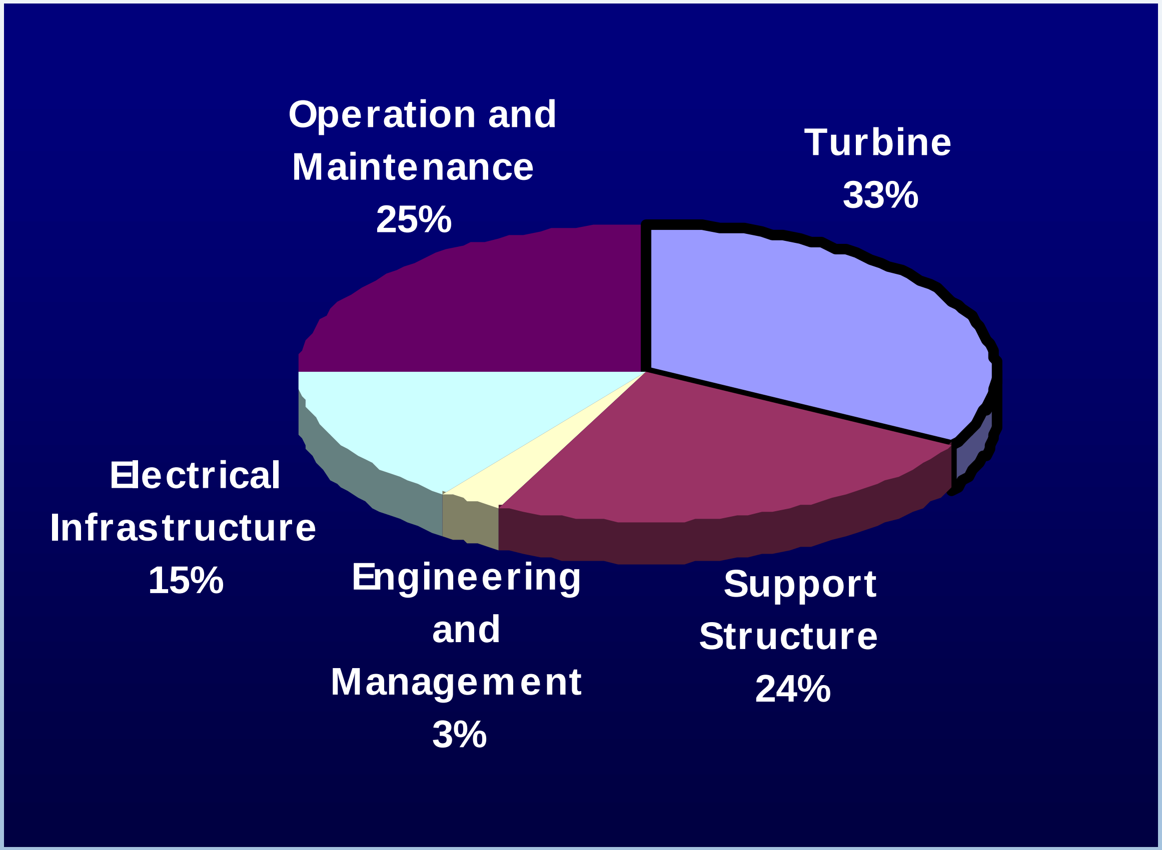
↑ **Regulatory Uncertainty**

↑ **Risk Uncertainty (weather, public acceptance, reliability, insurance)**

↑ **Currency Exchange Rates**

Offshore Wind Economics

- US projects may be feasible now with incentives, RPS, PTC, etc.
- System costs need to decrease for large scale viability
- Only about 1/3 of the cost is in the production of the turbine



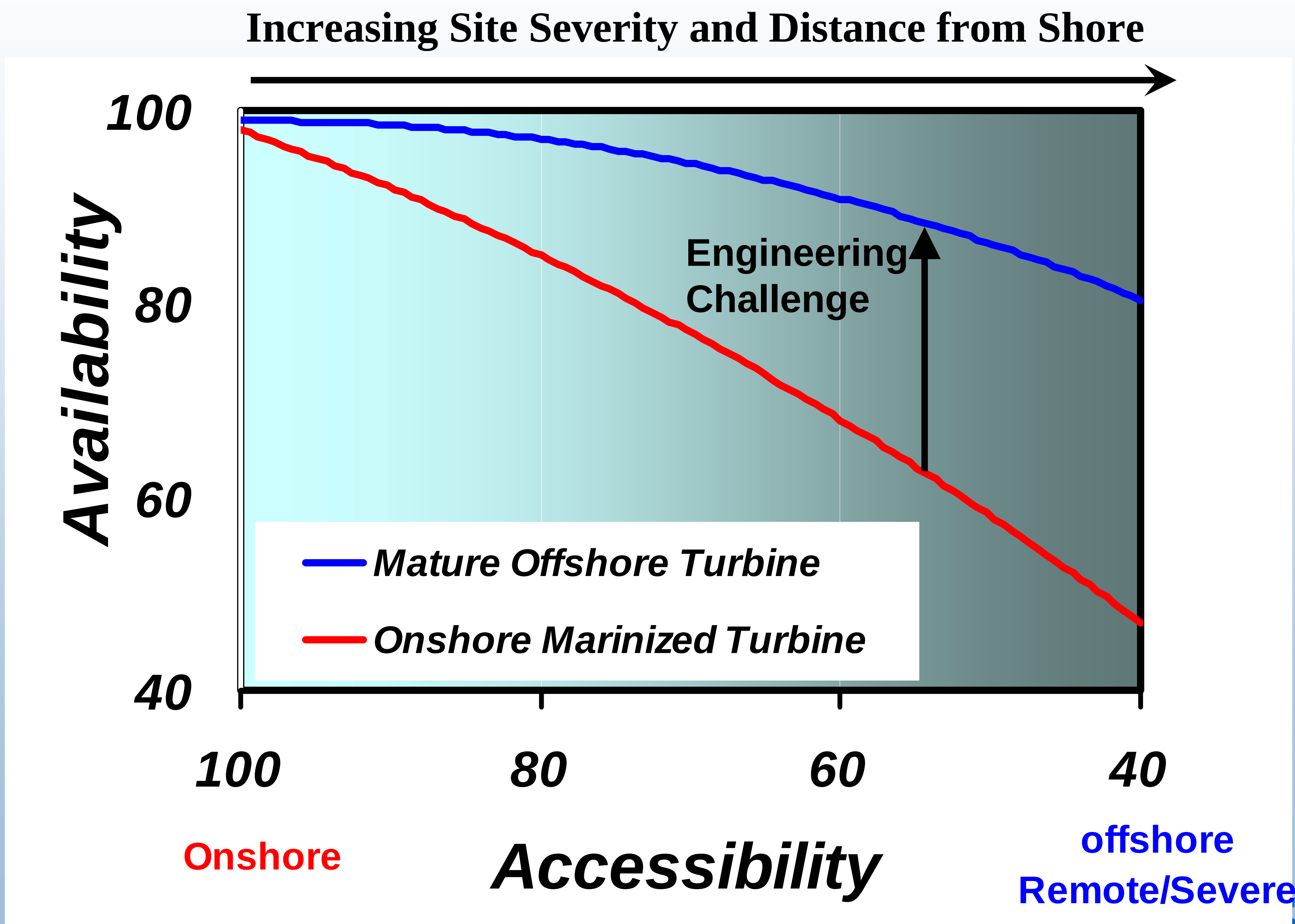
(Typical numbers derived from NREL cost model and ***CA-OWEE report 2001)***

Reduce Offshore Operating Costs


Credit: GE Energy

- Develop new high reliability designs.
- Develop new designs for in-situ repair
- Develop condition monitoring and advanced self-diagnostic systems to minimize cost of repair.

Offshore Turbines Must be More Reliable



Improve Reliability with Testing


Photo: GE Energy

Full-scale Component Testing

- Field deployment foolish without component verification – coupon to full-scale
- Increased needs with turbine size
- Increased reliability requires more extensive testing

- Field testing – System verification land and sea
  - Deployment stages – How to prove a system seaworthy?
  - Baseline measurements for condition monitoring
  - Failure rates – parameter tuning

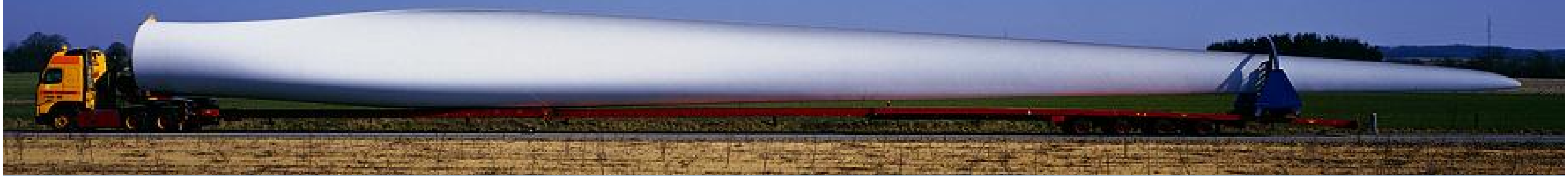
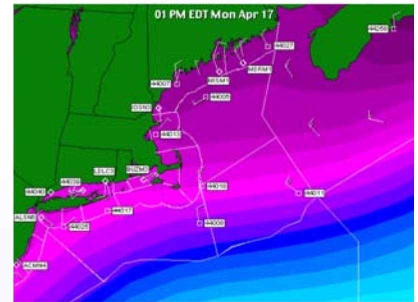


Photo: LM Glasfibres

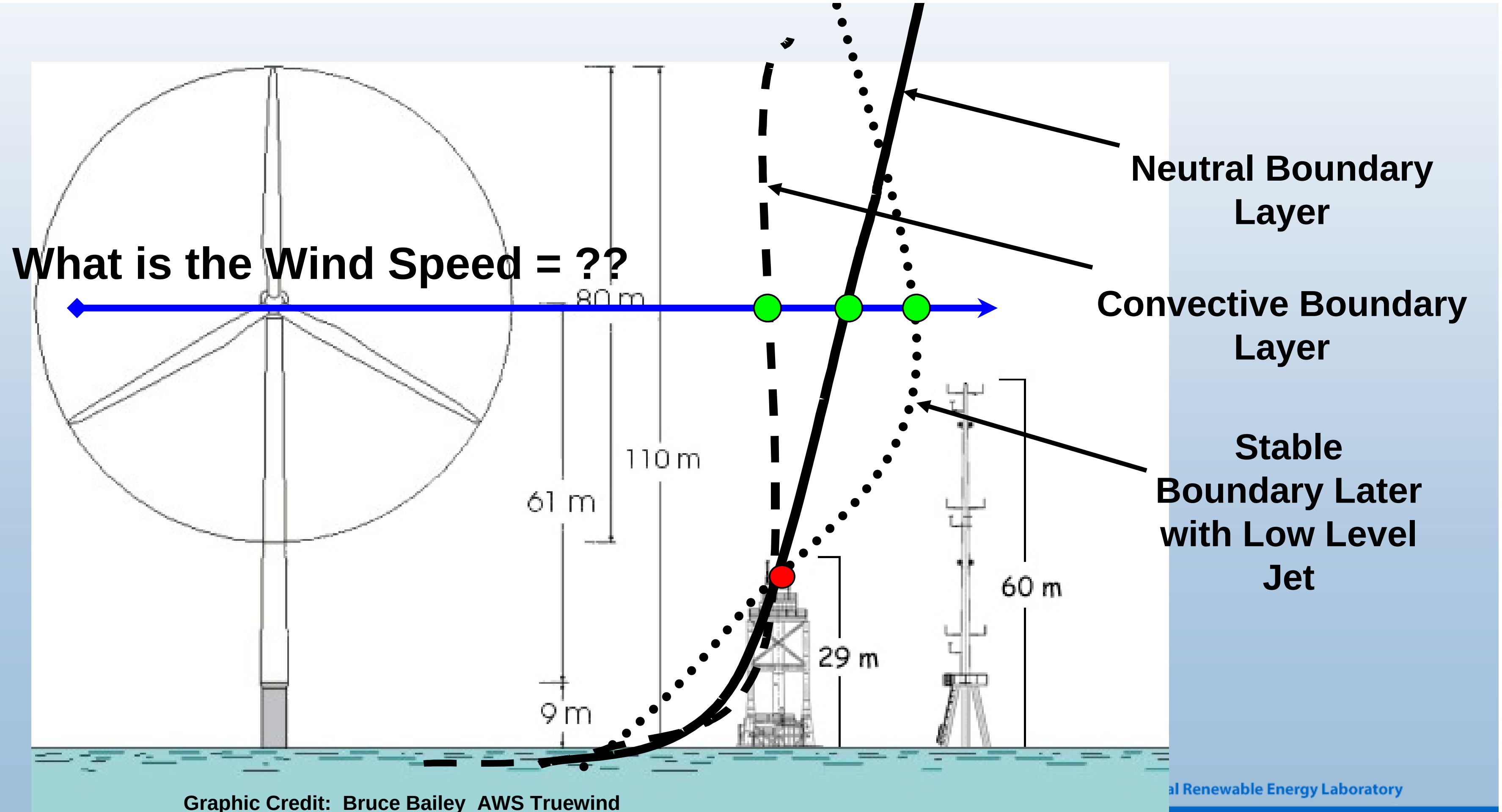
Minimize Work at Sea



- Lower Installation costs
  (up to 20% of total project)
  Garrad-Hassan
- Widen weather windows
- Reduce large vessel dependency
- Improve forecasting

Understanding Offshore Wind

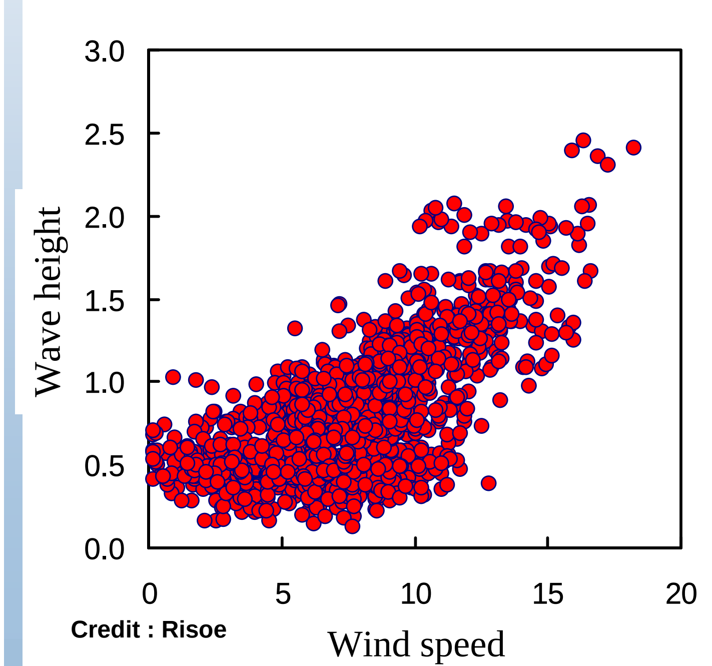
- Methodology for wind measurements without MET towers!
- Methodology for hybrid wind data from multiple sources.
- Validate wind speed/energy potential – from meso-scale to micro-scale.
- Understand boundary layer – stable vs. unstable, wind shear variations



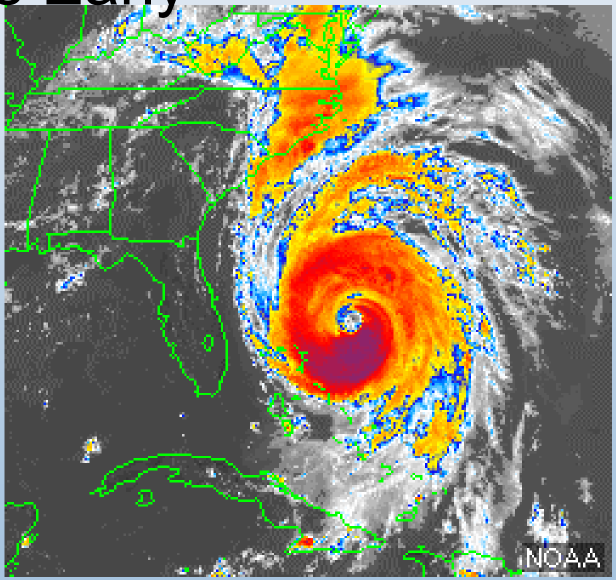
Graphic Credit: Bruce Bailey AWS Truewind

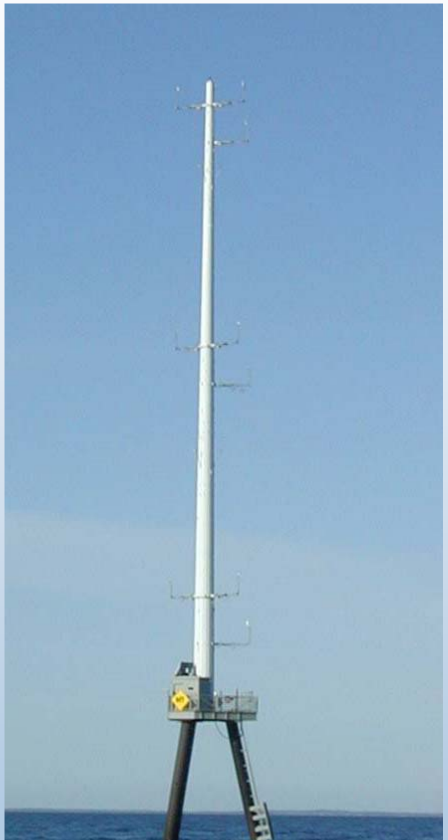
Assessment of Wind/Wave Performance and Design Site Requirements

- Meteorological Tower
- Wind Resources
- Physical Ocean
- Sea Ice
- Site Monitoring Begins Early



Credit : Risoe



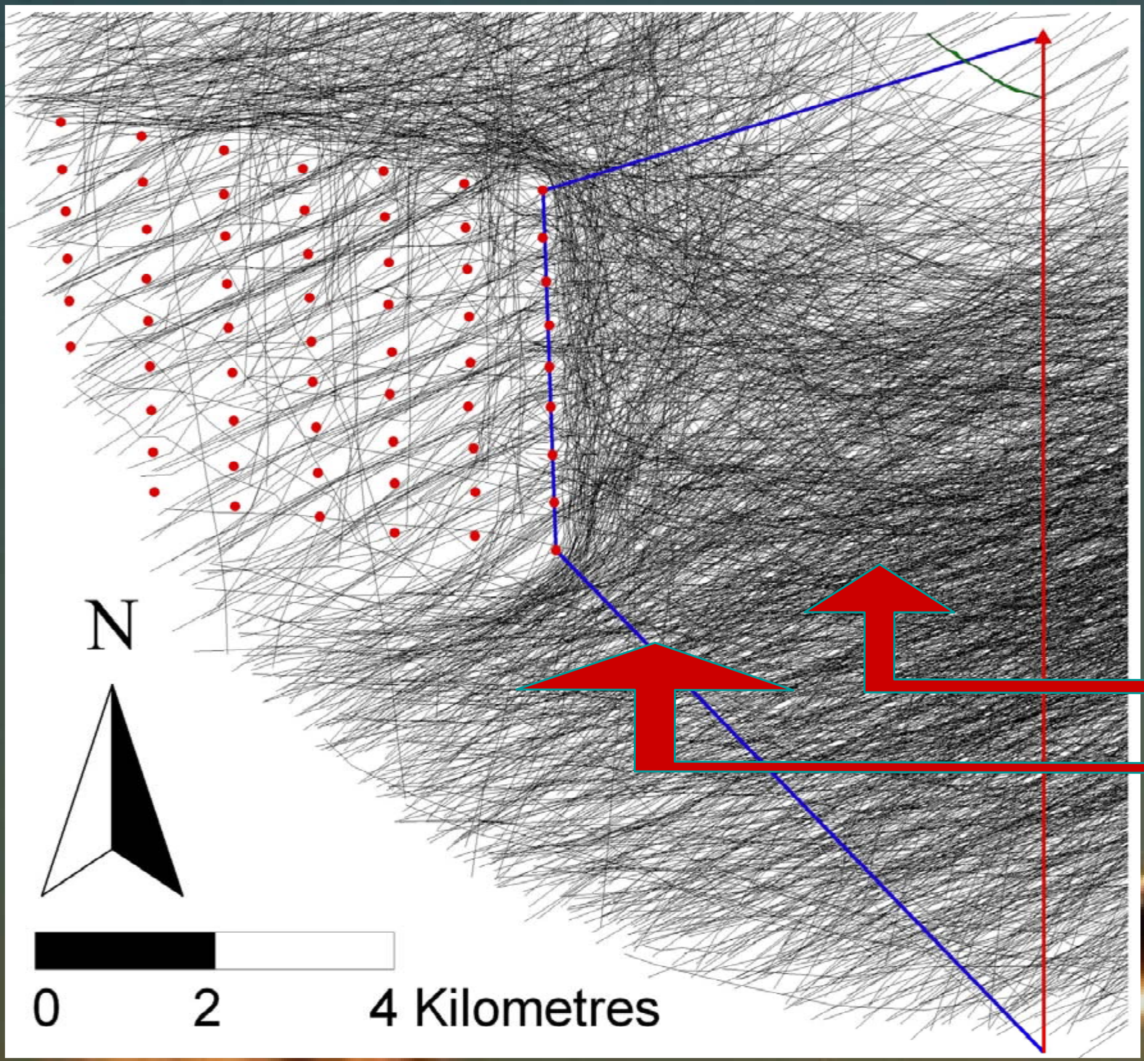


Capewind MET Tower 60-m

Offshore Project Development Depends on Accurate Long Term Knowledge of the Wind Speed

Radar registrations of waterbird flocks at Nysted (Rødsand), Denmark, Autumn 2003. Also shown is the change in waterfowl tracks during daytime and nighttime (Credit: Danish National Environmental Research Institute [NERI]).

Nysted Migrating Birds



Operation (2003):

Response distance:

day = c. 3000m

night = c. 1000m

Offshore Turbine Suppliers

Turbine Manufacturer	Turbine model & rated power	Date of availability	Offshore Operating Experience
Bard Engineering	VM - 5 MW	2008-09	Onshore prototype 2008
General Electric	GE – 3.6-MW	2003	Commercial inactive
Multibrid	M5000 - 5 MW	2005	Onshore 2005
Nordex	N90 - 2.5 MW	2006	Offshore Demo 2003
RePower Systems	5M - 5 MW	2005	Offshore Demo 2006
Siemens	SWT-2,3 - 2.3 MW	2003	Commercial
Siemens	SWT-3.6 - 3.6 MW	2005	Commercial
Vestas	V80 - 2 MW	2000	Commercial
Vestas	V90 - 3 MW	2004	Commercial

Thank you

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